DOCUMENTS DEPARTMENT

5/S

SAN FRANCISCO
PUBLIC LIBRARY

GOVERNMENT INFORMATION CENTER
SAN FRANCISCO PUBLIC LIBRARY

REFERENCE BOOK

Not to be taken from the Library

3 1223 90187 2920
DOCUMENTS DEPARTMENT
SEP 4 1969

Digitized by the Internet Archive
in 2016

https://archive.org/details/sanfranciscocomm1966arth

MODEL OF SAN FRANCISCO HOUSING MARKET

CRP

SAN FRANCISCO
COMMUNITY RENEWAL PROGRAM

TECHNICAL PAPER NUMBER 8

SAN FRANCISCO COMMUNITY RENEWAL PROGRAM

MODEL OF SAN FRANCISCO HOUSING MARKET

The preparation of this report was financed in part through a Community Renewal Program Grant from the United States Housing and Home Finance Agency under the provisions of Section 405 of the Housing Act of 1959.

C-65400

Arthur D. Little, Inc.

January 1966

*352.5
L721m

GS 70

SAN FRANCISCO
PUBLIC LIBRARY
DOCUMENTS DEPT.

TABLE OF CONTENTS

		Page
I	INTRODUCTION	1
II	SOME QUESTIONS CONCERNING THE CRP MODEL	2
III	MODEL STRUCTURE	8
	A. MODEL OPERATION	8
	B. MODEL ELEMENTS	11
	1. Housing Stock	11
	2. Space Transitions	20
	C. MODEL FLOW CHART	32
IV	MODEL RESULTS	36
	A. TUNING OF THE SIMULATION MODEL	36
	B. ANALYSIS OF INITIAL MODEL OUTPUTS	36
V	EXTENSION OF THE CRP MODEL	44
	A. REPROGRAMMING OF THE PRESENT MODEL	44
	1. Reduction of Detail	44
	2. Output Summary	44
	B. EXTENDING THE PRESENT MODEL	45
	1. Endogenous Location Changes	45
	2. Rent-Pressure Relationship	45
	3. Yield Calculation	45
	4. Owner-Occupied Housing	45
	5. Population Feedback Loops	46
	6. Extension of Public Actions	46
	7. Monitoring and Confirmation of Preferences by Survey Research Techniques	46
	C. EXPANDED SIMULATION MODEL	46
	1. Inclusion of Industrial and Commercial Sectors	47
	2. Reallocation and Population Movement Patterns	47
	3. Regional Model	47

LIST OF TABLES

Table No.		Page
1	Neighborhood by L Category	14
2	Location Category Definitions	16
3	List of J Housing Types	17
4	List of Possible JcL Combinations	18
5	Condition Categories	19
6	New Construction - Comparison of Investment	37
7	Comparison of New Units Constructed	38
8	Increase in Households and Net Dwelling Units	41
9	Condition of Structures	42
10	Simulation Model - Private Market Residential Investment	43

LIST OF FIGURES

Figure No.		Page
1	Program Layout in the Computer	12
2	San Francisco "Neighborhood" Divisions	13
3	Rent-Pressure Relationship	26
4	Abbreviated Flow Chart	34

I INTRODUCTION

The San Francisco Community Renewal Program study included a substantial effort devoted to the development of a residential space "model". This model was constructed to simulate those factors that influence availability, price, type, and quality of the City's residential space. We have described the principal technical characteristics of the model in Technical Paper No. 1. In this report we concentrate on uses and limitations of the model and methods of analysis. We describe some additions and modifications made to the model since Technical Paper No. 1 was written, such as "accelerated aging" and development of "preference lists". Finally, we present results of some model computer runs that were designed to test the recommended Community Renewal Program. This report is intended to provide others with an understanding of why this effort was made and of its value to the study.

The word "model" is itself the source of some confusion. During several hundred years of experience and usage, the physical sciences have gradually developed a meaning for this word that is somewhat different from normal language. The physical scientist usually recognizes quickly what is meant by the term, but others less acquainted with its use in this special sense will often be led to incorrect (and generally overoptimistic) expectations.

The term "model" can be defined as an effort to describe the more important characteristics and relationships of a real-world system or activity with a series of mathematical and statistical relationships. These relationships represent individual component events and their interactions within the system. This definition, however, fails to provide a full understanding of what is meant by the term; it fails to assess the implications of how the model can be employed and what limitations it is apt to possess. For example, since the model will cover only important features of the real-world system, not all features, it obviously has sources of error, errors that cannot be easily removed. It is necessary, therefore, to exercise considerable skill and caution, both in planning for the use of a model and in interpreting the results it provides. It is this very practical area of model utilization that receives primary attention in this paper.

II. SOME QUESTIONS CONCERNING THE CRP MODEL

In discussions of the San Francisco Community Renewal Program (CRP) Model, a number of questions have repeatedly arisen. The answers to these questions provide a background on the Model's general nature and the pattern of its use, and form a good introduction to specific results described later.

1. Can the Model be used to develop urban community renewal plans, or other plans for improvements to the City of San Francisco?

In general, the answer to this question is "no". The model is not a "black box" that can take a set of input values and convert these into a specific plan for action by the City authorities. If a specific plan is fed into the Model, it cannot even determine whether or not this is the best possible plan for a given set of circumstances. The Model is, however, a tool to assist experienced planners in evaluating results that might be achieved through following a given course of action. It is not a substitute for experience and judgment, but it is a means for permitting these qualities to be focused more effectively on the areas that require greatest attention.

These statements should surprise no one. Human desires and interests are highly diverse, while machines and models tend to be very rigid. The latter cannot be expected to completely solve a problem involving a variety of vital human inputs. A city is far too complex an organism to be completely subject to mechanistic analysis. A machine or a model can at best give us a starting point, and improve the efficiency with which human analysts and planners can operate.

2. Can the Model determine in detail the effects of carrying out a given program or set of improvements within the City?

Again, the answer is generally "no". The Model can be used to determine certain fairly broad effects of possible actions and it can furnish some information on detailed effects. Usually, however, it is necessary to supplement the latter information with additional study before it is possible to understand many important details of the influences of change. This is a result of our decision, early in our work, to concentrate on what might be termed a strategic model rather than on a series of tactical models.

A strategic model is designed to analyze over-all patterns and trends of the most important and fundamental characteristics of a system. We decided to develop this type of model after analyzing the types of action that a city can take to improve the quality of its residential housing. These actions, while important, are quite limited; they include zoning laws, code enforcement, provision of amenities, public transportation and utilities, and to a limited extent, the direct provision or subsidy of some types of housing. The primary source of residential housing is represented by investment decisions involving private capital. The city's actions can provide leverage that may increase or decrease the flow of capital to various types of land usage, but it cannot provide a substitute for healthy investment from private sources. Under these conditions, it seemed to us most important that any model developed be concerned with a description of the system within which private investors operate. The impact of alternate public actions can then be evaluated by simulating the influence of these actions on the interrelated elements of this system.

A tactical model is concerned with limited portions of an over-all problem, and is generally developed to attain a detailed understanding of these portions. For an urban renewal plan, for example, a model might be developed to study the mobility of urban populations, in an effort to determine the probable movements of people who are displaced as new construction occurs. Some tactical models are inevitably incorporated in any strategic model; for example, a model of the pattern of aging and deterioration of housing units in the city is an important component of the strategic model we have developed. In general, however, a tremendous variety of tactical models is possible, and their value and utility often cannot be determined until specific needs for them arise. Therefore, we decided to construct a strategic model, believing that the data and material collected for this purpose would have high applicability in any tactical studies required by later, specific plans.

3. How accurate is the Model?

The accuracy of the Model cannot be determined with presently available data. In theory, the accuracy of the Model could be studied by acquiring detailed data for different periods of time, say, between 1950 and 1965, and by starting the Model in 1950 and seeing if its results duplicated the actual events of the later years. The period of 1950 to 1960 could be used to determine if the calibrated Model can accurately describe events occuring after this calibration period. However, we simply do not have the necessary data over a suitable period of time to conduct such a checking process. The Model was designed to employ 1960 Census data for inputs; these provide the best and most reliable source of information on many characteristics of the population of San Francisco. Unfortunately, the detailed data from the 1950 Census that might have been used for calibration and testing purposes are no longer available in a form permitting the necessary cross tabulations. The Model was

calibrated to the construction activity in San Francisco during the period 1960-1964 by an extensive series of "tuning" runs. The accuracy of the Model, however, can be checked only after several years.

In general, the Model is not considered to be a highly accurate tool for forecasting the total future investment to improve housing in the City of San Francisco. There are a variety of reasons for this, ranging from technical problems associated with the development of input data to the intent involved in developing the Model. For example, it is obvious that the level of building in a city such as San Francisco depends not only on general economic conditions in the Bay Area, but also on psychological attitudes towards the construction of major new building units and the influences of competitive factors on potential investors both in the City and in surrounding areas. No particular emphasis was placed in the development of the Model on either forecasting general economic conditions or trying to cope with the psychological problems that influence large-scale building. The structure of the computer program is such that any analyses developed later in these areas could be inserted. Rather than being concerned with estimates of the absolute building level, the Model is primarily intended to develop an understanding of how the total building effort would be divided among competing possible forms of land usage, and how the residents of the City would be influenced by this division. The accuracy in this area, the division of effort among different forms of land usage, is important to the use of the Model, but this is an even more subtle and different subject to investigate than the general building level, for which there are adequate figures in recent years.

4. If we cannot be sure of the accuracy of the Model, how can faith be placed in the results that it produces?

This is a key question. Faith can be placed in the results only in accordance with the manner in which the Model is used and the care with which the results are interpreted. Successful employment of the Model will probably occur only through the process of making repeated runs and studying the relationships between the results of the different runs. Thus, we will be concerned mainly with relative rather than absolute accuracy, and the effect of many potential errors, although not necessarily all, will be greatly reduced. This procedure will be described in greater detail in Section IV, where examples are given of the results of several runs and the manner in which these results can be interpreted.

Even more important, the results of using the Model must be considered as suggestions rather than directions or proofs. The results will "suggest" that if certain actions are taken, certain events will occur. These events should not be accepted as proved, but should be evaluated in terms of experience and judgment. In some cases, it will immediately be clear that the Model results have a basis in logic that permits their acceptance. In other cases, it will be necessary to examine the analysis in considerable detail to determine why the results occurred. This process of determining the "why" of a set of results can often add substantially to

knowledge of the factors that influence a city's pattern of growth. Such results, in fact, are often the most valuable and productive of a model's use, since they can lead to improved insights and knowledge concerning a wide variety of municipal problems. In some cases, the logical explanations of why the Model produced certain results will not be entirely acceptable as representing the real world, and in these cases the results must be rejected.

These limitations present surprisingly few restrictions on the utility of the Model. Even in those cases where the logical structure of the Model and the results it produces cannot be accepted, the process of analyzing the results will often clarify the issues involved, lead to a better understanding of the true nature of the problems facing the city, and improve the ability to resolve these questions outside the Model.

5. Is the Model easy to employ?

At the present time, the Model is not easy to employ. It involves a relatively complex computer program of some 30,000 to 35,000 individual computer instructions. Between 12,000 and 15,000 items of input data must be employed on each run. The large majority of these input data will not change from one run to the next, so that having once been developed it can be used repeatedly. Nevertheless, for any new run devoted to the study of a new situation, it will be necessary to incorporate some new input data and, under some conditions, some new computer instructions. The use of the Model clearly requires considerable competence.

Interpretation of the Model results is even more demanding than its use. The outputs are of a form requiring skill to disaggregate and develop suitable tables, and the interpretation thereafter must be done by people who are not only acquainted with details of the Model but who are also thoroughly experienced with the City of San Francisco and with the characteristics of its housing and construction activities.

A number of steps could be taken to improve both the ease of developing new computer runs with the Model and the ease of interpreting the output. Some of these are described in Section V of this report.

6. Of what immediate use is the Model?

The Model is currently available to study any of a series of possible broad patterns of action that could be taken by the City of San Francisco to improve its residential housing. These studies can include, for example, the influences of code enforcement, the effects of changes in zoning laws, and the influences of different redevelopment techniques on private housing investment and on the total stock of such housing that would become available. Results can be provided in terms of the relative

stocks of housing of various types provided for different population groups, or in a variety of other forms. It is, therefore, a tool immediately available for use in studying the implications of different City policies.

7. What is the long-term value of the Model, and to what degree does this depend on further development of the computer program and associated input data?

As is not uncommon, the first version of this Model has taught us not only a great deal about the City of San Francisco, but also the types of Model improvements that would be desirable in the future. It is evident, for example, that the level of detail in the current model is greater than is necessary, and that removal of some of this detail would make it far easier and less expensive to operate and employ. Furthermore, fundamental improvements can possibly be incorporated in a number of areas. Typical of these is the development of more "feedback loops" in the Model, such as the influence of public housing expenditures on the tax rate and the influence of the tax rate on movements of residents into and out of the City. Finally, as we have gained experience in analyzing the Model outputs, we have determined ways in which the form of the outputs could be improved to make them more easily utilized.

The utility of the Model and its value can definitely be improved, therefore, through incorporating changes in the data input and output and through additions to the internal structure of the Model itself. In addition, the Model should both influence and be influenced by the City's data bank of information on its physical and demographic characteristics. One of the primary purposes in developing any strategic model is to determine in more structured form the types of information necessary to make appropriate and good decisions concerning civic policy.

The Model has, as one of its by-products, resulted in the development of a bank of data on the City and its inhabitants that is relatively unique and might not have been developed otherwise. These data were developed because of the Model's need for quantitative information about the important elements of urban system. Thus, the Model served to screen out from the vast amount of potential urban data that which is most significant. These data will have many uses. Furthermore, as more data is developed and is employed, it can lead to better inputs to the Model and thus to improve results. This pattern whereby a model improves data banks and the data banks in turn improve the utilization of the Model has many close parallels in the areas of physical sciences and has, in fact, been one of the main reasons for the success of these types of models.

8. In what way is the CRP Model unique or different from other models?

This question is answered more fully in Section III where we discuss briefly other models devoted to the study of city structure and the pattern of residential land-use. In general, the San Francisco CRP Model is unique in the extent to which it studies the market for residential land-use incorporating a large number of factors in great detail that have not appeared in earlier models, in particular nontransportation-oriented factors.

III MODEL STRUCTURE

A. MODEL OPERATION

The San Francisco simulation model has been designed to generate conditional predictions suitable for "impact analysis"[1]. It is intended to predict for city planners the impact of including alternative public actions in recommended programs.

Most public actions considered by planners involve housing. Whereas housing is not the only area the planner considers, actions intended to change the current state of the housing stock or to prevent future undesirable changes do represent a majority of his decisions. This model, therefore, is primarily concerned with predicting the effect of alternative actions on the City's housing stock. To have the model replicate housing in an urban system offers additional advantages: a single system is simulated in great detail without overtaxing the capabilities of the computer, and the successful simulation of the system may lead to development of a future, larger system that will include other relevant interacting subsystems.

The model simulates those factors of the urban system that determine housing unit quality, quantity, location, price, and type within a geographical area. It is more constricted than micro-analytical simulations of the interaction of several markets, as described by the work of Orcutt, Greenberger, Korbel, and Rivlin.[2] It concentrates instead on elements and relationships that are significant in the single geographical market of San Francisco housing.

To construct the model, we borrowed market structure generalizations from economics. Additional hypothesis testing and development were required, however, to select operating characteristics or rules for the decision-making variables or elements replicated within the model. These operating characteristics are symbolically expressed to replicate the behavioral and economic motivations of the decision makers who interact in the "real world" housing market. The reliability of the Model is largely dependent on the accuracy of these rules or postulates. In addition to decision-making elements, the model includes elements that represent the housing stock in the 1960 census. Model outputs are detailed predictions of the state of the housing stock at various time periods.

---

[1] cf. Ira S. Lowry, "A Short Course in Model Design," Journal of the American Institute of Planners, xxxi, No. 2, May 1965, pp. 158-166.

[2] Guy H. Orcutt, Martin Greenberger, John Korbel, Alice M. Rivlin, Micro-Analysis of Socio-Economic Systems: A Simulation Study, New York, Harper and Bros., 1951.

Arthur D Little Inc

Outputs are generated by simulating an equilibrium-seeking system that is never allowed to reach equilibrium. Certain basic components of this system are altered by the exogenous insertion of altered population figures at regular intervals. Exogenous constraints on the actions of decision-making elements can also be inserted at intervals to simulate restriction-type public actions.

Households are allocated by the model at periodic intervals. The Model is programmed to simulate the adjustment of the housing market to pressures generated by these allocations in view of institutional and governmental constraints. Household allocations are an important part of the Model operation, but, although recorded in the computer print-out, they are not the desired final output. Instead, they alter the rents for each of the locational, type, and quality housing categories monitored by the model. The rent changes then react with construction costs, rehabilitation costs, and physical aging rates to alter the housing inventory.

The operation of the Model is based on matching, in the computer, existing stocks of housing with potential "users". This process is determined by the relative need or desire for particular types of housing by categories of users. Changes in the amount or quality of housing occur when the users of space, because of an increase in their number or an increase in their ability to pay, create a "pressure" for certain types of housing, that is, a demand that exceeds the available supply. In time, a high pressure causes rents to rise. Changes in the housing stock are generated within the computer to relieve this pressure if the change or "transition" is financially feasible. Financial feasibility is determined by comparing the cost of making the change with the anticipated future yield. If this comparison indicates that profitable development conditions exist, the computer adds an appropriate number of new dwelling units to the inventory of the City's housing stock; makes a notation of the transition cost in a summary of total construction investment; and subtracts a number of older units from the inventory to account for the demolition necessary to make room for the new units. The computer then computes the resulting shifts in pressures, rent levels, and vacancy rates. When all effects have been accounted for, new inputs are fed in and the process repeats. In this way, over a series of iteration periods, a new configuration of housing usage is generated, simulating the physical development of the City's housing market. This process is repeated for nine two-year periods, providing an 18-year forecast in a complete run.

Public action programs and policies are introduced into the simulation as they affect the operation of the market, either by interfering with, or influencing, or controlling its functioning. Such actions take the form of zoning ordinances prohibiting certain changes in the use of space; code enforcement and renewal projects "artificially" introducing changes in space use where profitable development conditions may not exist; financial measures, such as cost subsidies or mortgage guarantees, that can affect the price and thus the quantity and/or quality of housing available; and public improvements that can alter the relative attractiveness of neighborhoods and thus affect the demand for housing, perhaps inducing

spontaneous private investment in rehabilitation or construction in such areas. The resultant effect of the alternative public action programs and policies on the allocation of housing usage may be evaluated in terms of City goals and objectives. In this way, a time-phased program of public actions may be selected to attain the objectives of renewal.

In summary, then, the model simulates the interactions and effects on residential housing of (1) public policies, programs, and actions; (2) investment behavior of the private market; and (3) the location decisions of households.

The conceptual lineage of this model is close to the household distributing model presented by Professors Herbert and Stevens in their work for the Penn-Jersey Transportation Study.[3] In our Community Renewal Program Model, no one factor is assigned major importance in allocation of households to dwelling units. Although our method is different than that suggested by Herbert and Stevens, the assumption is implicit that households seek a group of attributes when choosing a dwelling unit and location, rather than consider only the accessibility attributes of that location.[4] Our Community Renewal Program Model differs from the Herbert-Stevens model in that it does not develop an optimal solution to the allocation problem. The elegance of linear programming is sacrificed in order to simulate a wider range of detailed interactions.

Only the advent of large-scale computers has made possible the development and utilization of a model of this scope and magnitude. The model consists of approximately 35,000 computer instructions that govern the relationships and operational characteristics. Some 15,000 data items, specified by 35,000 input numbers, are required to identify the components of this system representing the housing market and the population of the City of San Francisco. These data items must be stored in the computer memory. As large files of information representing the City must be accessed frequently and in a random fashion, a large disc or drum storage capacity is required, rather than magnetic tape. We utilized one of the largest available commercial computers, an IBM 7094 with a 1301 disc file on line. Most of the computer program was written in FORTRAN IV, while certain subprograms (such as table look-up, packing,

---

[3] John D. Herbert and Benjamin H. Stevens, "A Model for the Distribution of Residential Activity in Urban Areas," Journal of Regional Science, vol. 2, No. 2, Fall 1960, pp. 21-36.

[4] The present model is not uniquely suited for predicting the impact of alternate transportation networks, as it considers the transportation factor as only one of the utility-providing attributes of a location. Furthermore, the elements of this model have been selected primarily for their ability to simulate the systems that determine the housing stock of an urban area, rather than the system which governs the transportation of goods and services over space.

unpacking, disc interphase, and special indexing) were written in assembly language. The program layout in the computer is shown in Figure 1.

In Figure 1, Blocks A, B, and C each represent one core load. When Block A is through executing, it is overlaid by Block B. Block B, Block C, B, C, etc., are executed until the last period and branch are completed.

Block A reads data, puts data on disc for future access, initializes, sets up public action files, etc. Block B computes which period we are in and which public action branch we are taking (branch dispatcher in Block B). It then executes public actions and other actions which can change the data configuration during processing. Next, this block ages the stock if other than the first period. Block C allocates populations according to their preferences to the stock (MA table). It then computes and executes profitable projects. Then it recycles and allocates again, and computes and executes profitable projects again. Either having reached equilibrium (no further projects) or having gone a maximum number of cycles in Block C, control would be transferred back to Block B.

Execution of the total program takes approximately two hours of computer time for a nine-period run (representing an 18-year simulation). As indicated in Section V, we anticipate that certain components will be collapsed to reduce detail so that both memory requirements and computer running time will be shortened.

B. MODEL ELEMENTS

1. Housing Stock

a. Neighborhoods

San Francisco was divided into 106 "Neighborhoods" (Figure 2). Each Neighborhood is approximately the size of a census tract, although Neighborhood boundaries are not necessarily the boundaries of census tracts. For convenience in using information from the Census Bureau, Neighborhood boundaries follow the boundaries of the Enumeration Districts.

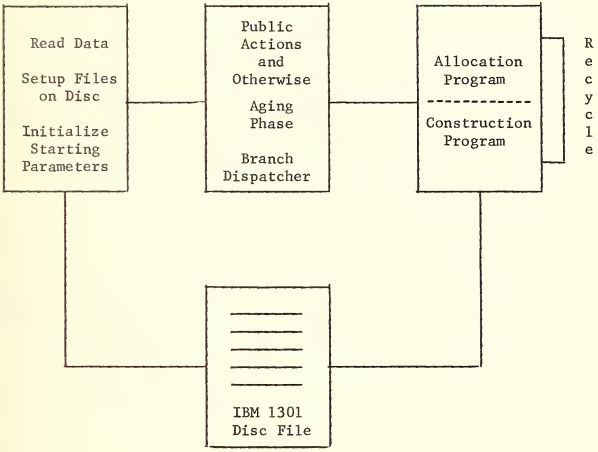
The Neighborhood is the smallest geographic area that can be identified in the simulation run. A redevelopment project, code enforcement, or a new high-rise apartment building can be placed in a given Neighborhood, but its position within the Neighborhood is not stated in the Model. Neighborhoods were chosen to represent as closely as possible areas with similar amenities, qualities of housing, or predominant housing types (e.g., single family vs. apartment dwellings).

b. Location categories

As a result of our studies on amenities and other factors distinguishing areas of the City, a "Location number" was assigned to each Neighborhood. Table 1 lists Neighborhoods by Location categories. The

FIGURE 1

PROGRAM LAYOUT IN THE COMPUTER



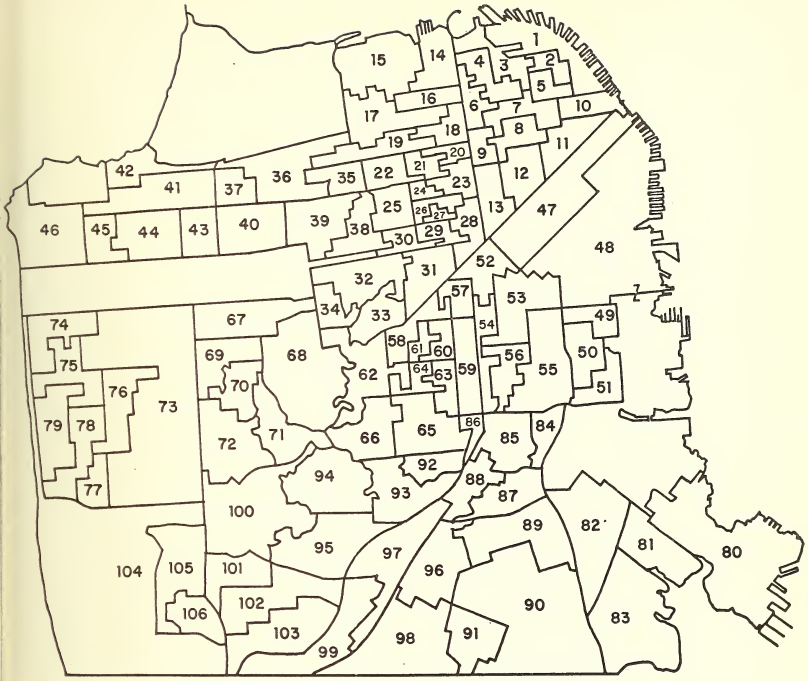


FIGURE 2

SAN FRANCISCO "NEIGHBORHOOD" DIVISIONS

TABLE 1

NEIGHBORHOOD BY L CATEGORY

L	Neighborhoods
1	33 50 51 62 66 84 85 92 93 102
2	68 70 94 100
3	
4	7 32 80
5	4 8 18 20
6	17
7	49 64 65 74 81 82 83 87-90 95-99 103
8	39 41 44 45 46 69 72 73 75-78
9	42 71 79 101 104
10	55 56 58 59 61 63 86
11	2 34-38 40 43 67
12	1 3 5 9 10 11 12 13 21-31 47 48 52 53 54 57 91
13	6 14 15 16 19 60
14	105 106

fourteen Location categories were set up according to Table 2. Hilly Neighborhoods were first separated from those predominantly level. A tabulation of the housing units in each Neighborhood was made, and the predominant housing type (single family, 2-4 units per structure, or 5 or more units per structure) and its average rent were identified. These factors were then combined to determine the Location category.

c. Fracts

The fundamental unit of housing in the computer is the dwelling unit (d.u.). In order to keep inventories of dwelling units commensurable among different housing types, and to keep the inventory of space in the City within the memory capacity of a large computer, we invented for Model purposes a land unit that we call a "fract". In current Model runs, a fract is equal to two acres. There are 4,980 fracts of residential land in the City (including vacant land available for residential development). Each fract is located within a specific Neighborhood; the total number of fracts in each Neighborhood does not change throughout a run. Each fract is homogeneous with respect to its space type and condition; a fract cannot have mixed land use within it. While a given fract lies within the boundaries of its Neighborhood, a fract is not necessarily a contiguous group of parcels; rather, a fract represents a grouping of parcels in different parts of a Neighborhood having a common housing type and condition. It follows from this that although a Neighborhood can be located geographically, a fract is located only as being within a given Neighborhood. Transitions in use of space and housing (new construction, conversions and mergers, or changes in condition of the stock) occur a complete fract at a time.

d. Land-use type: J types

Dwelling units are divided among 22 categories characterized by tenure, number of rooms, and structure type. Table 3 shows the number (J type) assigned to each dwelling unit type.

J Numbers 9 and 10 are reserved for two special cases. J-9 represents public structures, such as libraries or fire stations, that are not to be occupied as dwelling units, but are built on land previously in residential use. J-10 represents vacant land available for residential use.

Not all dwelling unit types are represented in every Location category. For instance, there are so few owner-occupied single family units in L-4 Neighborhoods that J-3, 5, and 7 were excluded. In L-7, 8, 10, and 11 there are so few one-room units in 5+ structures that J-22 units were grouped with J-24. Table 4 shows which dwelling unit types exist in sufficiently large numbers in each Location category to be included as a separate category in the Model.

TABLE 2

LOCATION CATEGORY DEFINITIONS

L	Topography	Modal Structure Type	Range of Mean Monthly Rent
1	Hilly	SF	$0-140
2	Hilly	SF	140-275
3	Hilly	SF	275+
4	Hilly	5+	$0-75
5	Hilly	5+	75-115
6	Hilly	5+	115+
7	Level	SF	$0-125
8	Level	SF	125-175
9	Level	SF	175+
10	Level	2-4	$0-75
11	Level	2-4	75+
12	Level	5+	$0-75
13	Level	5+	75-115
14	Level	5+	115+

TABLE 3

LIST OF J HOUSING TYPES

J	Structure	Tenure	Rooms
2	Single Family	Rent	1-2
3	Single Family	Own	1-4
4	Single Family	Rent	3-4
5	Single Family	Own	5-6
6	Single Family	Rent	5-6
7	Single Family	Own	7+
8	Single Family	Rent	7+
9	Public Structures		
10	Vacant Land		
12	2-4	Rent	1
14	2-4	Rent	2
15	2-4	Own	1-4
16	2-4	Rent	3-4
17	2-4	Own	5-6
18	2-4	Rent	5-6
19	2-4	Own	7+
20	2-4	Rent	7+
22	5+	Rent	1
24	5+	Rent	2
25	5+	Public Housing	3-4
26	5+	Rent	3-4
27	5+	Public Housing	5+
28	5+	Rent	5-6
30	5+	Rent	7+

Arthur D. Little, Inc.

TABLE 4

LIST OF POSSIBLE JcL COMBINATIONS

j \ L	1	2	4	5	6	7	8	9	10	11	12	13	14
2	x	x	x			x	x	x	x	x	x	x	
3	x	x				x	x	x		x	x		
4	x	x	x			x	x	x	x	x	x	x	x
5	x	x				x	x	x	x	x	x	x	
6	x	x	x			x	x	x	x	x	x	x	x
7	x	x			x	x	x	x		x	x	x	
8	x	x	x		x	x	x	x	x	x	x	x	
9	All areas												
10	All areas												
12	x		x	x		x	x		x	x	x	x	
14	x		x	x		x	x		x	x	x	x	
15	x		x	x		x	x		x	x	x	x	
16	x		x	x		x	x	x	x	x	x	x	
17	x		x	x		x	x	x	x	x	x	x	
18	x		x	x		x	x	x	x	x	x	x	
19	x		x	x	x	x	x	x	x	x	x	x	
20			x	x	x	x	x		x	x	x	x	
22			x	x	x						x	x	
24			x	x	x	x	x		x	x	x	x	
25	x		x			x			x		x		
26	x		x	x	x	x	x		x	x	x	x	x
27	x		x			x			x		x		
28	x		x	x	x	x	x		x	x	x	x	x
30	x		x	x	x		x			x	x	x	

e. Condition

The J number, Location category, and condition of a dwelling unit are sufficient to specify the kind of housing in the Model. We divided housing into four condition categories as shown in Table 5.

TABLE 5

CONDITION CATEGORIES

Condition 1	Sound
Condition 2	Needs minor repairs
Condition 3	Deteriorating
Condition 4	Dilapidated

These condition categories represent a compromise among several methods of classification. Condition 1 and 2 are included in the Bureau of the Census "standard" condition. Condition 3 corresponds to the Census condition "deteriorating" plus "standard with plumbing lacking". Condition 4 corresponds to "dilapidated" plus "deteriorating with plumbing lacking".

The condition categories are used in six different ways:

1. People perceive differences in the quality of housing and react. Those who can afford high rentals will normally look first for Condition 1, with Condition 2 as a possible alternative. Those who can afford only minimal rents will avoid Condition 1 and normally look for more space per dollar, or lower condition housing.

2. Dwelling units in better condition normally command a higher rental than those in worse condition.

3. Conditions 3 and 4 are generally considered substandard dwelling units and are subject to a code enforcement program, if instituted in the appropriate Neighborhood. When code enforcement is applied to a Condition 3 or Condition 4 dwelling unit, it must be raised to Condition 1 during the succeeding period.

4. Housing deteriorates in time to a lower condition state. See Technical Paper No. 2, in which the Aging Model is discussed.

5. "Normal yield" for a lower condition unit is generally greater than for a higher condition unit. This is used primarily in the formula:

Market Value = Current Rental/Normal Yield

The effect is such that if two properties are currently realizing the same rental income, the property in better condition will command the higher market value, based on its probable future income.

6. The cost of rehabilitating a unit from Condition 4 to Condition 1 is higher than from Condition 3 to Condition 1, which in turn is higher than the cost of rehabilitating a unit from Condition 2 to Condition 1.

2. Space Transitions

a. Public actions

As discussed earlier, the purpose of building a model of the housing market is to simulate the results of decisions made by private developers, owners of residential buildings, and households seeking shelter, and to measure the impact that various public-action programs would have on these decisions and thus on the state of the housing. The following is a list of public actions that the model can simulate, with a brief description of each. Note that public actions may affect housing directly, restrict the options of private developers, or tend to encourage the kind of desired action.

1. Zoning: Two zoning numbers can be entered for each Neighborhood. The first number is the maximum number of fracts that can be built with large apartments, that is buildings with 5+ dwelling units (J Types 21 and above). If a large apartment house project is being considered for this area, the computer first checks whether there are already the maximum number of 5+ fracts in the Neighborhood. If the number of 5+ fracts already built is equal to or greater than the maximum number, the large apartment project cannot be built. If fewer than the maximum are currently in 5+ usage, then the project may be built if it is economically feasible. The second zoning restriction number in the building table is the maximum number of fracts with buildings of two or more dwelling units (J Types 11 or above).

A change of zoning policy may be simulated by changing these zoning restriction numbers.

2. Location table: It is possible to simulate a change in the amenities of any given Neighborhood by changing its Location category. In this case, different households will seek housing in this Neighborhood, so that the demand picture for housing would thus be changed. An example of how this could occur would be if the City were to change amenities of a given Neighborhood, perhaps by building a park.

3. Assessment: A change in the assessment rate, or any other factor affecting the normal yield, can be simulated by changing the normal yield of a given JcL housing type.

4. Rental: The rental value for a given JcL can be changed externally.

5. Capital improvement: Any fract can be designated for a capital improvement and J Type 9 can be built on that fract. J Type 9 represents public property not usable for residential purposes, such as fire stations, parks, libraries, etc.

The means of choosing fracts for this public action is of some interest. Either the Neighborhood or the Location can be explicitly specified. In the event that Location only is specified, the computer will search various Neighborhoods within this Location category to find a suitable fract, with a specified J type and condition code. A further specification may be given to indicate whether the condition code is to be matched exactly, or whether any property in this condition or worse is suitable for applying this fract action.

6. Binary flags: There are six binary "flags" that can be turned ON or OFF for each fract in the City. These are handled in the following manner.

We assume that two projects will not occur on the same property within a two-year cycle period. Thus, when a transition has occurred on a given fract the computer turns one flag ON, signifying that this fract is not available for another transition in this time period. Flags on all fracts are turned OFF at the beginning of the next time period.

A different flag is used to signify that a given fract is owned by a public agency or is unavailable for private market transitions, until this flag is turned OFF exogenously.

A third flag indicates whether or not a fract is available for occupancy for residential users, in spite of its ownership by a public body. In other words, the City may purchase property for a redevelopment project and allow households to continue to occupy the housing for a few years. This land remains unavailable for transition in the private market.

A fourth flag signifies a fract on which code enforcement has been applied. If this flag is ON, and the property is in substandard condition, some transition must occur during this time cycle to bring the property up to code. When all projects have been executed for which the market yields satisfy the necessary criteria and the property remains in substandard condition, it must then undergo a transition even if uneconomic. The computer will search for all possible transitions available for the property, and choose the transition with the highest yield.

The last two flags are used to designate fracts in a rehabilitation or a redevelopment area. In either case, the transition cost is reduced (by 10 percent for a rehabilitation area and by 20 percent for a redevelopment area), simulating the kind of financial or financing aid that the City would normally offer to those improving their property or building new structures in such an area.

7. Code enforcement: Code enforcement may be applied to a given percentage of units in designated Neighborhoods. The computer chooses a random number for each substandard fract; if the random number shows that this fract has code enforcement applied against it, then the code enforcement flag is turned ON. If code enforcement is applied to a standard unit, no action is taken.

8. Construction costs: Aid for the construction of certain J types can be simulated by changing the construction costs of a given transition. For instance, special aid may be given to improve large apartment house units from Condition 4 to standard. The costs in this category can be reduced to simulate this policy.

9. Household preferences for housing: If it is expected that a sociological change will take place resulting in changes in the preference list entries for any household group, this can be simulated by exogenously changing the appropriate preference lists.

10. Aging rates: If it is expected that a public policy acts directly on the aging rate for a housing type in a given Location category, this can be simulated by a direct change in the aging probabilities for the housing Location type.

11. Rental: The rent-paying ability of any household group can be changed, as well as the rent-paying profile for this group. This public action may be used to simulate the effect of a rent subsidy to certain household types.

12. Direct fract action: In addition to the above actions, a fract can be changed directly by externally changing the J type, condition, or any of the flags for this fract.

b. Private market transitions

1. Yield and rent: Although public actions represent one mechanism by which transitions are brought about in space types and land use, the more important mechanism of transition in the simulation model is that associated with the "yield ratio", representing decisions by private developers.

We have shown that residential property is described in terms of land-use type (J), condition (c), and location or amenity (L) attributes. With each JcL type are associated two parameters or values, rental and normal yield. The initial rental values are the

average rents for each JcL type of property, obtained from a special analysis of the 1960 Census data. Rentals for each JcL are updated in the model, as discussed below.

Developers and property owners make their decision on the basis of many criteria, including economic and personal factors that a simulation model could not hope to replicate. We feel that in the long run, however, land-use decisions will respond more nearly to the value of economic yield than to any other individual indicator. By yield, we mean, roughly, the income of a property divided by either the amount of money currently invested or the market price of the property. Thus,

Rental (JcL) / Market Value (JcL) = Normal Yield (JcL)

In addition to net return on investment, the yield figure must include normal or average values for out-of-pocket expenses. Specifically, the yield covers such items as:

1. The risk-free interest rate
2. Provision for the risk appropriate to this kind of investment
3. Other financing rates
4. Normal expected vacancy rate
5. Taxes and insurance rates
6. Upkeep, maintenance, and management.

It is clear that many of these items vary from property to property, from condition to condition, and in different locations of the City. In a fashionable location of the City, the risk provision may be minimal (in fact, this component may even be negative in an area expected to appreciate in value). Provision for upkeep, maintenance, taxes, and insurance may be higher for dwelling units in better condition. There is no provision for building manager, elevator, or other expenses in a single family dwelling that one might need in a large apartment dwelling. Normal yield thus depends on type of housing, condition, and location. The normal yields, as a function of housing type, condition and location were determined through a special survey of real estate sales in San Francisco.*

The rules adopted in this simulation for the execution of private market transitions or projects is as follows:

---

* L. K. Loewenstein and R. Recht, "Variations in Rates of Return," Appraisers Journal, April 1965.

1. A transition represents the change of one fract to a different J type or a different condition.

2. A transition will be executed whenever the yield for this transition is equal to or greater than the normal yield for the type of space resulting from the project, provided no external constraints forbid it.

External constraints include:

1. Zoning restrictions

2. A single fract may not undergo more than one transition during any two-year period

3. Provision is made for the public designation of certain fracts in anticipation of redevelopment projects.

Two different formulas for yield are used depending on the nature of the transition. If the transition involves rehabilitation, conversion, or merger, the yield formula depends upon the increased rental from the rehabilitated, converted, or merged property, and the transition costs:

$$\text{Transition Yield} = \frac{\text{Rent (New Condition)} - \text{Rent (Old Condition)}}{\text{Cost}_J \text{ (Old to New Condition)}} \qquad (1)$$

For the building of a new structure, however, yield depends on the total rental to be realized from the new structure and the cost of the project, including both the building costs and the market value of the property in its old state.

$$\text{Transition Yield} = \frac{\text{Rent (New JcL)}}{\text{Cost}_{JcL} \text{ (New Construction)} + \text{Market Value (Old JcL)}} \qquad (2)$$

where Market Value (JcL) = Rent (JcL)/Normal Yield (JcL)

The yield ratio is defined as:

Yield Ratio = Transition Yield/Normal Yield (JcL)

Yield ratio must be greater than unity for a transition to be executed by the private market.

The cost for carrying out each kind of transition in new construction, rehabilitation, conversion and merger (for each housing type, condition, and location) were determined by a special study.*

---

* Community Renewal Program Technical Paper No. 4.

Total construction and rehabilitation transition costs are cumulated so that at the end of a simulation run we have estimates of the total private market investment by period, for an 18-year period. We do not total market value of the property in its former state; this is consistent with our policy of following only transitions that result in a physical change.

2. Space pressure

1. Pressure: Space pressure is computed as the ratio between the demand for a housing type and the supply. Demand is computed as the sum of the "relevant households", where a relevant household is one that would normally seek this type of property, and could affort to pay the rent if it were vacant. To determine relevant households and to compute pressure, the Model performs an idealized allocation of households to dwelling units. We first describe the rent computation, and then discuss household attributes and the household allocation.

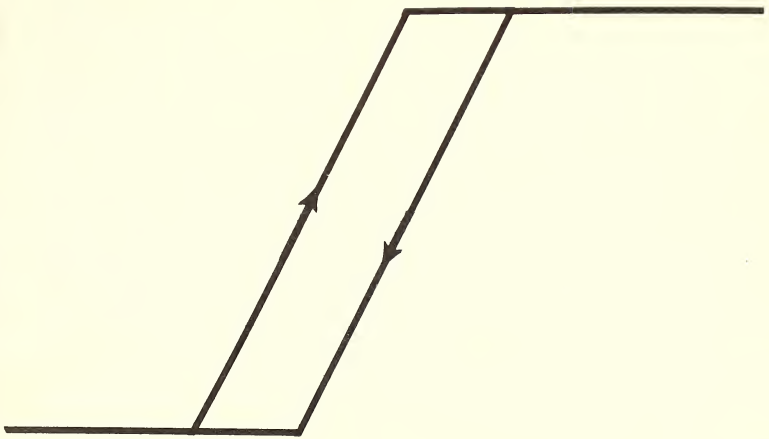
2. Rent computation: During each cycle of each period the Model recomputes the rental value for every JcL in the Model. This computation makes use of a value of space pressure, outlined above. The graph of Figure 3 is used in the rental computation. The graph was developed on the basis of data on San Francisco vacancy rates and rents and on the empirical work of Black and Winnick in other cities.*

The meaning of the graph is as follows. If the space pressure is well above 1, this indicates that a larger number of households desire the particular housing type than there is stock available, and rents are caused to increase at a maximum rate. If pressures are well below 1, this indicates substantial vacancies, beyond the normal turnover. In the latter case, there would be a strong incentive for owners to reduce rents in order to increase the occupancy rate of their property. If pressures are only slightly lower than 1, the situation is ambiguous. The owner would like to reduce his rent slightly in order to fill the property; however, in doing so, he may also have to reduce the rent for those units that are currently occupied. Thus, he may gain more by keeping the rents fixed and tolerating the slight vacancy. Two different curves are used for rent as a function of pressure. The pressure at the time of the rental computation is compared with pressure one year ago. If the pressure is increasing, landlords will assume a basically more optimistic outlook than if the pressure is decreasing. Thus, the upper curve is used for rising pressure and the lower curve

* D. M. Black and L. Winnick, "The Structure of the Housing Market," Quarterly Journal of Economics, vol. LXV, No. 2, 1953.

Figure 3

RENT - PRESSURE RELATIONSHIP



.5 .6 .7 .8 .9 1.0 1.1 Pressure

is used if pressure is decreasing; we have a rent-pressure "hysteresis" effect. No matter how high the pressure on a given property, rents do not increase faster than 4 percent a year. Similarly, even with a very high vacancy rate, it is assumed that rents will not decrease more than 4 percent a year, due to natural inertia and the averaging effect of some properties feeling the pinch of vacancies more than others.

3. Households: To identify groups of households that have similar housing needs, Locational preferences, and housing budgets, we divided the population into 114 household types, using the following attributes:

a. Household type

1. No children, head under 60 years
2. No children, head over 60 years
3. Households with children

b. Household size: (1, 2, 3+), (1-2, 3-4, 5+) or (1, 2, ...) depending on Type and Color

c. Color

1. White
2. Negro
3. Oriental and others

d. Annual income

$0 - $2,000	$0 - $4,000	$0 - $4,000
2 - 4,000	4 - 6,000	4 - 6,000
4 - 6,000	6 - 8,000	6 - 8,000
6 - 8,000	8 - 10,000	8 - 12,000
8 - 15,000	10 - 15,000	12,000+
15,000+	15,000+	

Choice of set depends on Type and Color

In order to simulate the spread of rent-paying abilities exhibited in any given household group, we developed rent-paying distributions for each household type, based on actual rents paid in 1960. For most household groups, the range of rent paid follows closely a Gaussian or "normal" probability curve. This curve was truncated at the top and bottom 10 percent of each household group, defined as the minimum and maximum rent for the group.

The rent-paying distributions of household groups with the very highest or very lowest incomes are skewed towards the upper tail. Some households, with incomes over $15,000, spend much more than the

average for the group. The same is true of households with very low incomes, since the average rental is quite low. No one pays less than 0 dollars, but a few households pay a good deal higher than the average. We approximated these distributions with a logarithmic normal curve, also truncated at the upper and lower 10 percent.

The normalized index, however, is based only on the household types currently occupied by the households in question. Therefore, we further modified the index by using the list of those household groups that are similar in household type, size, and color, but have different incomes. If the household group of the next higher income group (the "aspiration" group) lives in a higher preference index JcL than the household group under consideration, this JcL probably represents one that would also be desirable to the household group under consideration. Similarly, if a housing type is inhabited with a lower preference index by the next higher income group, a housing type is represented that is probably less desirable. By the same reasoning, if household units in lower income categories live in a certain JcL type with a higher preference index than the household group under consideration, this housing unit is probably less desirable than a housing unit where those in lower income categories live with a lower preference index. To reflect this, the following weighting function was applied to the indices of the household group and its aspiration and "de-aspiration" groups:

Aspiration Group	-4	-3	-2	-1	0	+1	+2	+3	+4
Weighting:	-1/81	-1/27	-1/9	-1/3	1	1/2	1/4	1/8	1/16

Housing types were then sorted on the weighted index numbers. The top 50 JcL housing types compose the preference list for the household type, except that the fourteen most frequent JcL types for each household type are in any case included. The 50 JcL's determined by the above method are then ranked by rent to obtain the final preference list.

For those households eligible for public housing, the relevant public housing types are entered at the end of their preference list, so that all households that could afford to live in private housing and for whom private housing was available would be allocated first to the private housing.

4. Household preference lists: The special tape obtained from the Bureau of the Census contained data on a 20 percent sample of all households in the City of San Francisco, including household type and residential housing type (JcL). From these data we developed raw counts for the number of each household type in each housing type. By dividing the raw counts by the total number of each household type in the sample, we calculated the percentage of each household type residing in each housing type. These were then sorted to develop a list for each household type showing in order of frequency the JcL types inhabited.

From these lists we noted that a few popular housing types comprising the majority of the dwelling units in the City accounted for most of the entries high in the list of almost all household types. Our preference list should, however, include not only the main housing types available but also those housing types that may be rarer but are desired by segments of the population.

For this reason, we divided each of the percentage numbers by the number of housing units of each JcL type, providing an index which is normalized to the number of households and the number of housing units. The effect can be seen in the following example. Suppose that a given household type lives in equal numbers in two JcL's. Suppose, furthermore, that one JcL type exists in abundance in San Francisco and the other is so rare that 50 percent is inhabited by this one household grouping. Although the percent of households in the housing units are the same, the normalized index would be much higher for the rarer housing type, indicating that that housing type is particularly desired by the household type.

c. Generalized Aging Model

There are three directions in which housing condition may change. Let us examine these in terms of the alternative opportunities that are open to the suppliers of shelter. Such alternative economic opportunities form the criteria for individual decisions concerning the amount of money that will be expended on the maintenance, remodeling, and building of dwelling units. The results of these decisions determine the directional impact of the aging process upon the condition of the dwelling units in the housing inventory.

1. Condition improvement: If the costs of improving the condition of a dwelling unit are exceeded by the extra rents users will pay because of the condition improvement, the suppliers of these dwelling units will increase their net income by expending the funds necessary to improve the condition of the structures. Such net income gains expand as suppliers continue to improve these conditions, as long as the necessary costs are less than the resulting increases in total rents that accrue from the improving conditions. In these instances, rehabilitation will take place as discussed in the previous section.

If the opportunity for rental increases is greater than the total cost of constructing a new building, then the existing structure can profitably be torn down and a new structure will replace it. The cost of such a new structure includes allowance for the income lost by razing the old building, in addition to the cost of razing and rebuilding.

2. Accelerated aging: If the money saved by cutting back on maintenance, (and thereby allowing conditions to deteriorate) exceeds the loss of revenue that accompanies such downward conditional changes, then suppliers can gain in net income by allowing existing conditions to deteriorate. Such deterioration can be profitably allowed to continue as long as the cost savings exceed any rental reductions occasioned by the lower conditions they permit. Thus, standard units become substandard. We call this process "accelerated aging".

3. Normal aging: If the cost savings that go with undermaintenance are exceeded by the rental reductions occasioned by deteriorating conditions and if major improvements do not pay for themselves in terms of rental increases, then the suppliers have only one reasonable choice, to attempt to maintain the existing condition of their buildings with a minimum of expenditure. In this case we have "normal aging or deterioration"; the rate of deterioration or obsolescence depends on the degree of usage, the kind of structure, and the Neighborhood.

Owners of housing in a given Neighborhood will tend to maintain their housing uniformly. There are two reasons for such homogeneity. First, the opportunities that face the supplier are a function of the alternatives open to housing users. Users, however, are interested in more than structural type and housing condition; they also attach value to location. Therefore, in the eyes of housing users alternatives for housing in any given Neighborhood only exist within it, and in Neighborhoods with similar locational value. Thus, the opportunities facing landlords will tend to be uniform in a given Neighborhood as user alternatives are restricted to locationally linked alternatives. In addition, the houses of a Neighborhood tend to be reasonably alike in capital value. The owner of units with high capital value will be less permissive of condition deterioration than will be the owner of property with capital value primarily derived from capitalization of the income generated by its current users. The opportunities facing the suppliers within a Neighborhood will be evaluated with similar consideration given to the impact of their decision on capital values.

We have described how the model simulates the Type 1 situation. If yields are sufficiently high to motivate such actions economically, the model will simulate transitions to improve conditions.

As described in Technical Paper No. 2*, the "normal aging" (Case 3) can be described as a first-order Markov process. An "aging vector" is applied against the state of housing of each type and Locational category. The housing state is the number of units in

---

* San Francisco Community Renewal Program Technical Paper No. 2, Models for Condition Aging of Residential Structures, Arthur D. Little, Inc., 1964.

Conditions 1, 2, 3, 4 (and in vacant land). The elements of the aging vector represent the fraction of units that deteriorate each two-year period from a given condition to the next lower condition. The numerical values of these aging vectors were developed from a cross-sectional analysis of the data on number and condition of housing types in San Francisco, obtained in the 1960 housing census.

A random number is generated for each fract to control the aging process. (This and code enforcement represent the only two areas in the simulation model where stochastic processes are employed.) Suppose that 10 percent of a given housing type is expected to deteriorate from Condition 2 to Condition 3 in a two-year period. Suppose, furthermore, that there are 11 identical fracts in Condition 2 in a given Neighborhood. Then one fract is changed from Condition 2 to Condition 3, nine fracts remain in Condition 2, and a random number is drawn to determine whether the remaining fract is aged to Condition 3 (with a 10 percent probability) or remains in Condition 2.

The model uses the appropriate aging vector; this is the "aging process factor" that acts on the bulk of the housing stock. Thus, if no upward condition transitions are induced, and no incipient blight is indicated, then what may be considered a general obsolescence and aging factor is applied as indicated by the aging vector.

The following approach is taken to identify and simulate the aging process as it affects housing types that are undergoing accelerated condition deterioration, that is, to identify and simulate incipient blight (Case 2).

1. We define Q_1 (LJC) as the summation of households allocated to the next LJC in their preference list. (See Section b4 for a description of Preference Lists.) Preferences are listed ordinally by rent; insufficient rent-paying ability would prevent households from obtaining the next preference above the one they do obtain. After summation, the number of housing units desired is divided by housing density so that Q_1 is measured in fracts.

2. Next we compute "adaptive pressure" $P_1(LJC) = Q_1(LJC)/M(LJC)$, where M(LJC) refers to the number of LJC units available in the City. This pressure is computed to reflect the demand for LJC at the rental or value imputed if their condition were to deteriorate, that is, if their rents were equal to the rents that apply to LJC+1. (LJC+1 refers to the same LJC type in one condition lower.)

3. Next we scan economic pressure P_2 for each LJC and drop from consideration all LJC's except those where $P_2(LJC) < 1.0 - 0.0001 \times$ (annual rent per d.u.). This is based on the assumption that the owners of LJC's with complete occupancy at their

current rent, will not consider the possibility of lowering rents and conditions. Furthermore, such action will not appear feasible for dwelling units with high capital value, until there is a high vacancy rate. Therefore, the critical vacancy rate is an inverse function of value (0.0001 x annual rent per d.u.), so that the higher the value the lower P_2 must become before it is considered eligible for the application of an accelerated aging vector.

With the completion of the above three steps, the model is capable of identifying those LJC's that are underutilized but are highly desired by households whose rent-paying ability fails to qualify them by a slim margin. While such identification is interesting, it does not represent a necessary and sufficient condition for incipient blight. Several other conditions must also hold true.

4. $P_2(LJC+1) \geq .95$ - There must not be excessive vacancies present in the next lower condition. If there is a high vacancy rate, it is unlikely that it will be profitable to allow higher quality housing to deteriorate to condition (c+1).

5. $F(LJC)R_{c+1} \geq P_2(LJC)R_c$, where R_c refers to rent of an LJC, and F is the "fill" and equals $P_1(LJC)$ or 1.0, whichever is smaller. Here we are measuring the actual income that the owners of LJC's are receiving, either in rents or imputed value, and comparing it to the net income that would develop with rapid deterioration in condition.

If all of the above conditions are met, then the selected "LJC" will receive an accelerated aging vector, rather than the "normal" aging vector. The accelerated aging vector generally represents a rate of deterioration approximately 10 percent per year higher than the "normal" rates.

C. MODEL FLOW CHART

Figure 4 presents a very abbreviated flow chart of the computer simulation Model. A complete run will normally consist of nine complete periods, each period representing two years. Some comments on the individual steps in Figure 4 follow.

Step 1: All the initializing data for the run is entered into the computer, including current housing data, yield data, household preference lists, etc.

Step 2: For each time period, the housing stock is "aged", utilizing the aging vectors described under Generalized Aging Model.

Step 3: The target population and the public actions programmed for the period are entered.

Step 4: The public actions are executed.

Step 5: An allocation of households to housing fracts is carried out, utilizing the household preference lists, and availabilities and rents of each housing type in the Model. The pressure and resulting rent for each housing type is then calculated.

Step 6: A list of likely private market transitions (new construction, rehabilitation, conversion, or merger) is developed in the following manner:

1. Determine the housing type with the highest pressure. Search throughout the City for, first, a Neighborhood zoned for this kind of space and, second, a fract within this Neighborhood that can be transformed to the housing type in demand.

2. Compute a yield for this project, based on rent for the housing type in demand, the rent of the current space, and the transition cost.

There may be a large number of different fracts that can be converted to the type of housing we need. Some of the transitions may have yields that are less than the normal yield for this project and, therefore, are not economically feasible. Of those for which the yield is greater than the normal yield for this kind of transition, the computer identifies those with the highest yield and puts these into a list of potential transitions. Thus, a list of potential transitions is built up by identifying the space type with the second highest pressure, third highest pressure, and so forth, until a fixed maximum number of potential transitions (currently 80) is developed. Space transitions are not carried out immediately because there is no assurance that the transition with the highest yield relates to the space type with the highest pressure. It is likely, however, that a transition with the highest yield relates to a housing type with high pressure, as this kind of housing type will command a higher rent, and thus yield will be high.

Step 7: The transition execution phase uses the list of potential transitions developed in the previous step. The potential transitions are executed in order of yield so long as the transition is allowed by zoning restrictions, and the fract has not already undergone a transition in the period.

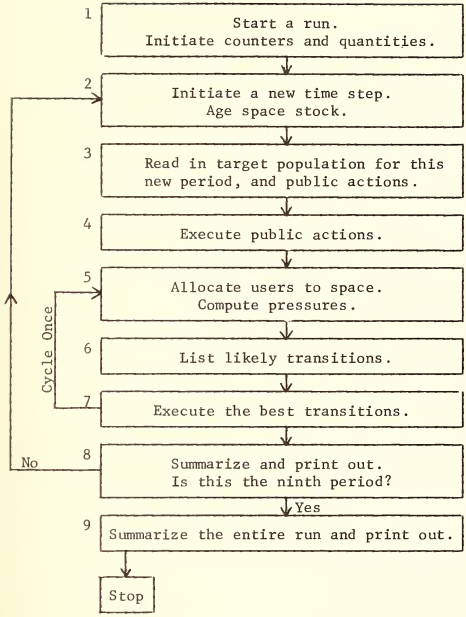
The simulation Model is programmed to perform any number of Allocate-List Transitions-Execute iterations (Steps 5, 6, 7) per two-year time cycle. In current runs, two such iterations per period are carried out.

Step 8: Such statistics as the detailed state of the housing, the household allocation, pressures, and rents for the period are printed out.

Steps 2-8 are then repeated until the total number of desired periods has been simulated.

FIGURE 4

ABBREVIATED FLOW CHART



Step 9: The results of the entire run are put on an output tape for special summary tabulations and printouts.

IV MODEL RESULTS

A. TUNING OF THE SIMULATION MODEL

In order to verify the operation and structure of the simulation model, it would be ideal to replicate some period of history and thus compare the simulation model results with actual events (new construction and rehabilitation of residential housing activity) in San Francisco. As indicated in Section II, there is insufficient data available over a period of time to carry out a good comparison. However, we were able to "tune" or adjust the model by using data available from City building permits, as a measure of new construction activity in recent years. Unfortunately, permits do not provide good data for rehabilitation, conversion, etc. Permits are not always filed, and they are not necessarily an accurate reflection of the cost and kind of modifications actually made. The model was tuned, to the extent possible, to new construction activity for 1961 through 1964, the period in which data were available. The "tuning" consisted of adjusting a few parameters that regulate total construction activity and the mix between single family, 2-4 unit buildings, and 5 plus unit buildings. These parameters are the relative normal yields of 1, 2-4, and 5+ unit buildings, and the length of the project file (see Section III).

The model replicated total new construction investment extremely well during Periods 1 and 2 (1961-1964; see Table 6). The number of single family housing units constructed was not replicated as well as the 2-4 and 5+ buildings in the period under consideration (Table 7). This is probably due to the fact that our concept of yield, based on rental revenue and investment, cannot be directly translated in the case of single family owner-occupied housing. Other considerations apply in owning one's own home. Also, it may be that the concept of economic pressure is not directly equivalent for single family owner-occupied houses as for the other types of housing.

B. ANALYSIS OF INITIAL MODEL OUTPUTS

Because the Model's primary strength lies in its ability to suggest the relative impact of public actions, a minimum of two runs is needed for any evaluation. Thus, to determine the impact of a specific program of possible public actions, the most meaningful evaluation compares a simulation of the market including public actions with another simulation excluding these actions. Therefore, one "base run" is needed as a conditional prediction of the housing future of San Francisco under stipulated conditions that do not include the plans or programs we desire to evaluate.

TABLE 6

NEW CONSTRUCTION

COMPARISON OF INVESTMENT

(Millions of Dollars)

	Actual San Francisco	Simulation Runs
Period 1 (1961-62)	$121.4	$121.7
Period 2 (1963-64)	155.7	156.6

Arthur D Little Inc

TABLE 7

COMPARISON OF NEW UNITS CONSTRUCTED

	San Francisco Actual				Simulation Runs			
	Single Family	2-4	5+	Total	Single Family	2-4	5+	Total
Period 1 (1961-62)	1,415	756	5,891	8,062	428	828	6,886	8,142
Period 2 (1963-64)	855	790	8,240	9,885	798	560	7,830	9,188
Total	2,270	1,546	14,131	17,947	1,226	1,388	14,716	17,330

This base run assumed a continually increasing population slightly in excess of the target population listed in the Community Renewal Program and with a somewhat higher income distribution, and it simulated only those public actions, including zoning and urban renewal projects, that are presently in force or approved.

The "public action run" was identical to the base run, except that it included a simulation of the type of code enforcement, zoning, clearance, and public housing actions that are recommended in the Community Renewal Program. The same populations were included in both runs as a test of the capacity of the market to carry out an "excess load". In other words, we tested the ability of the private market to increase the quantity and improve the quality of San Francisco's stock to meet the needs of the projected population. The public actions were simulated to test the efficacy of the recommended Community Renewal Program on the housing market and the Program's ability to encourage improvement in the quality of housing available to the residents of San Francisco.

Evaluation of these runs indicate that if the projected population income distribution can be realized, the private sector of the economy would be capable of continuing to provide most of the new housing units needed by an expanding San Francisco population. The model was programmed with a 16% increase in population between 1960 and 1978 (Table 8). The base run of the model indicated that with this increase in population there would be a corresponding 14% net increase in housing units. During this period, the simulated private market would increase the housing stock by 21% (gross) new units.

Although the net increase in the number of housing units did not differ significantly in the two runs, there was a significant difference in the number of substandard units in the housing inventory (Table 9). The public action run indicated that during the six years of the recommended program (Periods 3-6) code enforcement would reduce the number of these substandard and seriously substandard units by approximately 9%, while the total number of housing units was increasing. On the other hand, the increase in housing units brought with it an increase of 1,000 low quality units when code enforcement was not simulated. The effect of the Community Renewal Program, therefore, was to encourage some 5,000 dwelling units to be upgraded from substandard (Conditions 3 and 4) to standard housing (Conditions 1 and 2).

Comparison of private investment in the two runs indicates that the code enforcement in the Community Renewal Program would encourage a private market investment in rehabilitation at a rate 40% higher than in the absence of the code enforcement during the six years simulated (Periods 4-6; see Table 10). This additional private investment, together with the public housing recommended in the Program, was responsible for the upgrading of the housing quality.

This analysis also gave warning on the price or rent effects that would accompany improved housing quality. The decrease in number of substandard units brought with it an increase in rent of the remaining substandard units. The runs indicated that by 1978 these units could increase in rent at a rate double that of higher quality units. Consequently, in order to avoid imposing financial hardships on low-income households, code enforcement should be accompanied by an expansion of the supply of low-cost standard housing, as recommended in the Community Renewal Program. (The incentives recommended in the Community Renewal Program to induce the construction of these additional low-cost housing units were not programmed in the simulation.)

In making the analysis summarized above, the evaluating team was continually confronted with examples of the interdependence among the various components of the housing market. The public action run simulated increased zoning restrictions on construction of large apartment buildings in certain neighborhoods. These zoning restrictions altered the pattern of construction in other neighborhoods and also influenced the construction of single family and smaller apartment buildings. While the housing users and their preferences were identical in the two runs, the public action simulation run showed differences in the rent or price of certain housing units. These rather small price differences also influenced the location and types of construction and rehabilitation activity.

The analysis of the two runs provides the basis for increased confidence in the effects of the Community Renewal Program and confirms the usefulness of a model in dealing with a complex system. In addition, it raises interesting questions about the real-world system that is simulated. The apparent success of the model in simulating the complex decision-making activity, which we have termed the housing market, indicates that it is a valuable aid in gauging the impact of major plans and programs that may be considered by city planners and officials.

TABLE 8

INCREASE IN HOUSEHOLDS AND NET DWELLING UNITS

Period	Exogenous Household Increase	Dwelling Unit Increase - Base Run	Dwelling Unit Increase - Public Action Run
*1	1.75%	2.24%	2.24%
*2	3.50	4.80	4.80
*3	5.25	7.62	7.62
4	7.00	9.81	9.84
5	8.75	10.93	11.19
6	10.50	12.40	12.57
*7	12.25	13.33	13.21
*8	14.00	13.74	13.63
*9	15.75	14.22	14.36

* Note that the base run and public action runs were identical in terms of the public actions that had been programmed into the computer before Period 4 and after Period 6. Thus the first and last three periods indicate a simulation of the results that follow a cessation of the additional (Community Renewal Program) public actions that were simulated in the public action runs during the Periods 4-6.

TABLE 9

CONDITION OF STRUCTURES

	PERIOD 3 (1966)		PERIOD 6 (1972)			
			Base Run		Public Actions Run	
Condition	Number of Units	Percent	Number of Units	Percent	Number of Units	Percent
1	118,774	37.2%	131,714	39.6%	137,132	41.1%
2	163,388	51.2	163,584	49.0	163,680	49.0
3	24,690	7.7	21,822	6.6	18,046	5.4
4	12,232	3.8	16,124	4.8	14,908	4.5
Total	319,084	100.	333,244	100.	333,766	100.
Substandard (Condition 3 & 4)	36,922	11.5	37,946	11.4	32,954	9.7

TABLE 10

SIMULATION MODEL

PRIVATE MARKET RESIDENTIAL INVESTMENT

(Millions of Dollars)

	Base Run			Public Actions Run		
Periods	New Construction	Rehabilitation	Total	New Construction	Rehabilitation	Total
1-3	457.8	118.2	576.0	457.8	118.2	576.0
4-6	450.3	89.9	540.2	450.6	124.9	545.5
7-9*	279.7	71.4	351.1	262.2	46.4	308.6

* No Community Renewal Program in Public Actions Run

V EXTENSION OF THE CRP SIMULATION MODEL

As indicated in previous sections, the CRP simulation model of the residential housing market in San Francisco is operational, and has been turned over to the City Planning Department. In this section we outline several potential improvements and modifications that will make the model easier to use and that will extend its scope. We have grouped these into three categories. The first category consists of programming changes that will make the present version of the model more economical and easier to use. The second category consists of several fundamental changes that will permit the model to provide additional information concerning the operations of the residential market. These improvements will require additional research and additional programming, but can be added to the present model without altering its basic structure. Finally, the present model can serve as the basis for an expanded model that will include other elements of the urban system, or of a whole region.

A. REPROGRAMMING OF THE PRESENT MODEL

1. Reduction of Detail

As a result of our experience with the tuning and basic runs described in the previous section, it has become evident that the level of detail in the current model is greater than is necessary for most policy-testing runs that the Planning Department will wish to carry out. Some of the population categories, for example, contain comparatively small numbers of households that could be aggregated. Similarly, it would appear feasible to reduce the number of Neighborhoods without impairing the sensitivity required for most policy-testing runs. This reduction of detail will simplify analysis of the output, and will reduce the computer time and, therefore, the cost of an individual run.

2. Output Summary

The output summary can be made more flexible and responsive to the required analysis. With increased experience, it will become evident what information is most commonly required. The output summary can then be reprogrammed to provide this information in more convenient form. The summary tape should be put in a form that permits a variety of easy cross-tabulations by using a tabulation program such as ADLTAB (the Arthur D. Little Tabulation Program).

B. EXTENDING THE PRESENT MODEL

1. Endogenous Locational Changes

The factors that determine the Locational category of a given Neighborhood, such as mix of housing, average rent, etc., may change sufficiently over the period of the computer simulation run that the Neighborhood will change from one Locational category to another. A subprogram could be written that will monitor these factors, and automatically change the Locational category of such a Neighborhood when appropriate.

The current method of selection "L" areas would seem to lend itself to the development of such endogenous changes. The most important factor in defining these areas consists of similarities in the rents, type, and quality of units within a single "L". If the houses within a geographic area drop in value, this area can automatically be considered for a change in "L" designation, since it is no longer similar to those areas in which housing maintained its value and quality. Further research is required to establish realistic threshold values that will signal switches in "L" designations.

2. Rent-Pressure Relationship

In developing our relationship between rent and "pressure" (vacancy rate), we have utilized all available empirical data and economic theory. It would be desirable to study this relationship further and introduce any modifications arising from this further research. Since very little data appear to be available, this may require setting up a system of information collection for rents and pressure (demand) at a fairly detailed level, and observation of these over a period of several years.

3. Yield Calculation

It will be useful to disaggregate the components of the yield calculation, such as the city tax rate, mortgage rate, mortgage period, etc. This would allow the impact of public actions that affect each of these components to be studied more explicitly.

4. Owner-Occupied Housing

The basic yield mechanisms of single-family owner-occupied housing appear to be different than for multi-family or tenant-occupied housing, where the more conventional economic considerations apply. A more refined consideration of single-family housing starts would take account of such factors as impact of interest and tax payments on personal income tax, and the intangible benefits of owning a single-family home rather than renting a dwelling unit.

5. Population Feedback Loops

At present, the population projections are input to the computer model as exogenous variables. In practice the number and mix of population seeking to live in a city may be influenced by the availability of housing, the cost of housing, and, in the case of minority groups, the degree of discrimination. If research can determine the relationship between population and the housing variables, then these relationships can be incorporated into the model as "feedback loops".

6. Extension of Public Actions

We have programmed into the model the important public actions that directly affect the condition or availability of housing stock. There are several public actions possible, such as making information available, which may have an indirect effect on the condition or availability of housing. If these public actions and their effects can be quantified, that is, the relationships determined through research, then these could also be entered into the package of available public actions that might be tested.

7. Monitoring and Confirmation of Preferences by Survey Research Techniques

The preferences currently in the Model were drawn from the empirical evidence available in the 1960 Census cross-tabulation (see Section III). However, housing demand preferences may change over time; these changes should be reflected in the Model program.

Survey research techniques have been employed in other situations to obtain information similar to that needed for the development of preferences. Furthermore, such research would shed light on the appropriateness of preferences deduced from census cross-tabs. Thus, we could improve the Model's accuracy and move in the direction suggested by Professors Maisel and Winnick: "It is doubtful that reliable housing demand relationships will ever be formed until cross-sectional data are supplemented by longitudinal and attitudinal studies."*

C. EXPANDED SIMULATION MODEL

The following represent areas where the present simulation Model can serve as the basis for the development of a Model with greater scope. Development of such an expanded Model will clearly involve a substantial research effort.

---

* Sherman J. Maisel and Louis Winnick, Family Housing Expenditures: Elusive Laws and Extensive Variences, (Berkeley, University of California, Real Estate Research Program, Report No. 25, 1960), page 360.

Arthur D Little Inc

1. Inclusion of Industrial and Commercial Sectors

A natural extension of the residential Model would be to include the commercial and industrial building stock. In the case of San Francisco, a good start has been made in this direction through our collection of data on commercial and industrial buildings (CRP Technical Paper No. 5). Modifications in the categorization of building stock, establishments, and possible rent pressures will, of course, have to be made for these sectors. Extension of the residential model to these other sectors of the urban environment will allow the interactions and competition for land to be studied, and the impact of public actions on any of the three sectors to be determined.

2. Reallocation and Population Movement Patterns

The Model, as presently constituted, was designed primarily to determine the impact of public actions on residential housing stock. In order to determine the pressures for various kinds of housing stock, the Model does make an allocation of "users" or households to building types within neighborhoods and location categories. The present Model, however, is not well suited to determining individual population movement patterns, such as might be caused by any necessity for displacing households. These movement patterns could be made more explicit by inserting "friction" or "inertia" into population mobility rates; that is, the Model will incorporate turnover rates or vacancies in various household or housing categories to compute the number of individual units that would be available on the market. Using such turnover rates would make a detailed allocation more realistic and would allow the impact of a renewal program on migration of the displaced households to be determined more explicitly.

3. Regional Model

The present simulation Model can serve as a basis of an extended regional model. In such a model it would of course be necessary to make modifications in the scope and detail of the individual elements, to fit it within the framework of a regional Model. It would also very likely be necessary to make the role of transportation availability and commuting times more explicit. Ideally, a regional model should also include the commercial and industrial sectors so that the interaction of all these factors could be studied on a regional basis.

Arthur D Little Inc

#07-5-679